

HIGH-ENERGY LASER BLASTS METALS

A high-energy laser system shocks metal components such as hip implants and engine fan blades, making the parts more resistant to fatigue and corrosion.



■ Lawrence Livermore technicians align the neodymium-doped glass laser (pictured above), which offers a peak power of 3 billion watts, roughly equivalent to the power output of a nuclear power plant.

Imagine using a shotgun to shoot tiny balls—as small as grains of salt—at the surface of a metal, generating a compressive stress near the surface. In essence, that is what manufacturers call peening, and they have been doing it for years to reduce metal fatigue and corrosion. In the 1980s, researchers discovered that lasers couldpeen metals with deeper penetration, increasing their resistance to failure in high-surface tension applications. But creating a commercially viable, high-energy, high-repetition-rate laser to accomplish this task has been difficult.

Lawrence Livermore National Laboratory (LLNL; Livermore, CA) has developed a powerful, fast-firing laser that could help bring this peening technology to market. The neodymium-doped glass laser features an average 600 watts of power and can fire 10 pulses per second. Previously, lasers for peening could generate only one pulse every two seconds, making the process economically unattractive. While conventional peening reaches a depth of about 1/100 of an inch to instill compressive stress, LLNL's laser can penetrate four times deeper. This increase is critical to stop stress-cracking in engine blades, rotors, and gears.

Laser zig-zag. The key to the laser's commercial viability is its slab cavity design, which features reduced thermal buildup and wavefront distortion to achieve higher repetition rates. Laser light propagates through the slab in a zig-zag pattern to minimize wavefront distortions. In addition, the laser's gain medium is thin, providing more efficient heat extraction. BMDO funded the development of the laser at LLNL for optical imaging of space objects. Other contributors include the U.S. Navy, the U.S. Air Force, the Department of Energy, and the Defense Advanced Research Projects Agency.

LLNL has licensed the laser peening process to, and has a cooperative research and development agreement with, the Metal Improvement Company (Paramus, NJ) to develop laser peening as a commercial process. Work under the initial phase of the agreement is expected to last about two years. Part of this effort includes working with companies to laser peen test components for their evaluation. Commercial products manufactured with the technology, called LasershotSM Peening, are two to four years away from introduction.

Metal Improvement, the largest U.S. supplier of peening services, says that a new laser peening system using LLNL's laser will find applications throughout

the metal working industry. "There is definitely a need for this process," says Jim Daly, Metal Improvement's senior vice president. "Laser peening won't replace conventional shot peening, but it will be used in areas where deeper depths of compressive stress are needed." In general, the "deeper the compressive stress, the better damage tolerance," adds Daly.

Strengthening airplane engine parts, such as rotors, disks, and blades, will be one of the first uses of the new laser. The U.S. Air Force sees LLNL's laser peening technology as a way to address its number one propulsion concern—high cycle blade fatigue. Early tests have shown an increase of between 10 and 40 percent in metal fatigue strength, allowing engines to operate at higher stress loads without cracking. Other aviation industry studies have shown that engine blades—which can cost \$30,000 to \$40,000 each—last three to five times longer when treated with the laser peening process.

Hardening parts. Laser peening has additional uses in aviation as well as other industries. The technology could be used to increase the resistance of jet engine blades to damage from objects such as birds, ice, or stones, which can damage the edge of a blade. Once an object strikes and damages the fan blade's edge, the flaw can propagate through the blade, leading to accelerated blade failure and possibly the destruction of an engine. Beyond aircraft, laser peening could be used to harden the surface of hip joint implants, making them more durable. Other potential applications exist within the automotive, oil tool, marine, chemical, and power generation industries.

The laser also could be applied to x-ray lithography, for more precise integrated-circuit etching. LLNL's laser could produce the shorter wavelengths of light needed to produce higher resolution features as fine as 0.1 microns, possibly replacing conventional optical lithography techniques. IBM is building a \$700 million x-ray lithography facility using a high-power energy source called a synchrotron. If the company's technology is successful, then small producers who cannot afford a synchrotron (\$100 million) could use LLNL's laser (a few million dollars).

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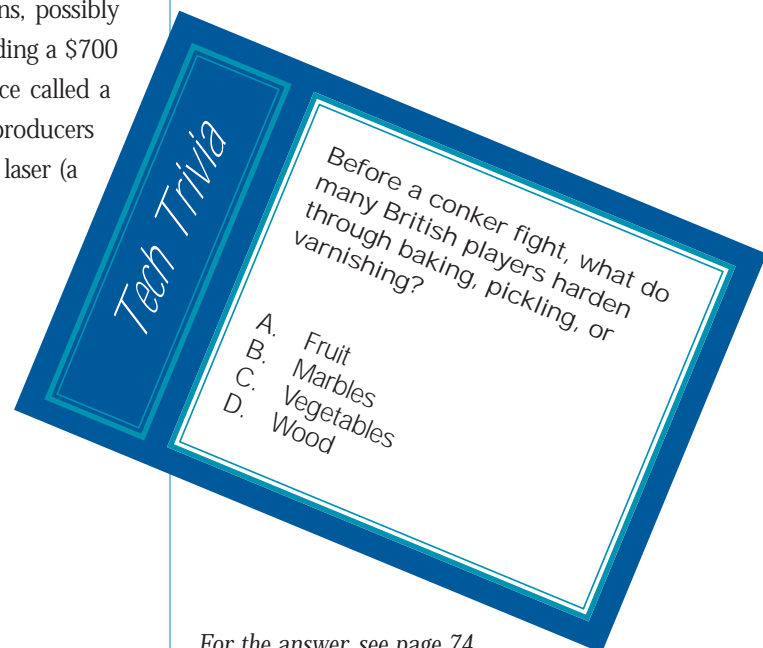
What Does It Mean to You?

Laser peening means jet engine components will be made stronger and last longer, thereby making flying safer.



What Does It Mean to Our Nation?

Laser peening may create a new industry that can increase the value of manufactured metal products such as hip joint implants and jet engine blades.



For the answer, see page 74.